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ABSTRACT

This report is a synthesis of materials delivered at the seminar at St. Wolfgang organized by the Austrian Government in 1968 under the auspices of the Council of Europe on "The Value of Natural Sciences in Adult Education." It links the problems posed with those discussed at the Marly-le-Poi course (1967). The following aspects of adult education are dealt with: its meaning, present position in adult education, and educational value. Discussed also are: individual process of development, evolution research, motivation, obstacles to dissemination of scientific knowledge, types of science education for adults, selection of material and system, and possibilities of popularization. (NL)

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sciences in adult education

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COMMITTEE FOR OUT-OF-SCHOOL EDUCATION

THE VALUE OF THE SCIENCES IN ADULT EDUCATION

Study Course organised by the Austrian Government
(St. Wolfgang - Strobl, 13th to 24th May 1968)

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NOTE

This report is a synthesis of material delivered at the course organised by the Austrian Government in 1968 under the auspices of the Council of Europe on

"THE VALUE OF NATURAL SCIENCES IN ADULT EDUCATION"

The seminar took place from 13 - 24 May at the Federal Institute for Adult Education in St. Wolfgang, near Strobl.

This report, based essentially on the texts of the various lectures, attempts to link up the problems posed at the Strobl course with those discussed at the Marly-le-Roi course (1967).

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INTRODUCTION

The organisation of adult education in the different European countries, its real aims, its gradual insertion into an integrated system of permanent education, all these are problems which at present occupy every government. The essential difficulties hindering their solution on the theoretical level derive mainly from their novelty. Adult education has only become necessary as a result of the continuous acceleration in the evolution of modern society.

At the course on "New trends in adult education", organised at Marly-le-Roi in May 1967, the Council of Europe established the basic theoretical alternatives which ought to guide the efforts of those organisations responsible for developing adult education to the extent it deserves if it is to form part of a new system of permanent education based on modern teaching methods, taking into account the enormous resources now available for diffusing information adapted to the needs and motivations of adults. Never before has technical progress, and in particular the improvement in methods of mass communication, opened such wide horizons for building a society of individuals responsible for their own lives, aware that this responsibility demands a new kind of education, characterised by the fact that it is never complete and by the possibilities it should afford for the perpetual reorientation of the individual person's activities.

Once these two tasks have been completed (studying the goal to be reached and the means available for reaching it), the content of the adult education programme still remains to be defined. We know how to dispense instruction intended for adults; the subject matter to be taught is still unknown. What must people be taught to satisfy their need to find their place and role in this world and in society?

Before referring to the different suggestions raised at St. Wolfgang, an answer must first be found to the following questions:

(1) What is meant by natural sciences?

(2) What place is at present given to the natural sciences in adult education?

(3) On what does the educational value of the natural sciences depend?

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In the second part of this report, we shall try, with the help of the various papers presented at the Course, to understand the following aspects:

(4) The question of motivation.

(5) The obstacles to be overcome before a science education scheme intended for a wide audience can show positive returns.

(6) The form such an education scheme must take.

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1. What is meant by natural sciences?

The very expression "natural sciences" is ambiguous; in order to understand it clearly it would be necessary first of all to define the word "natural", which is no easy task. The best solution would be to examine the meaning of the expression as used in the context of the various lectures.

The meaning which seems implicitly to have been given to "natural sciences" corresponds to the more complete French term "sciences exactes et naturelles", with the addition of mathematics, in so far as it is the privileged instrument of these sciences.

Rather than compose a list likely to be inadvertently incomplete the following definition (whose arbitrary nature will be compensated by its usefulness) might be adopted: the natural sciences include all those branches of science whose aim may be defined in "natural" terms in contrast to "symbolic" terms. This definition excludes what is currently known as the social sciences ("sciences humaines"), although it must include those aspects of psychology directly derived from physiology. It is, moreover, merely a synthesis encompassing all the topics dealt with at St. Wolfgang. It is a definition which does not, however, call in question the inter-connecting links (stressed particularly by Prof. Dr. Eder) binding all exact and social sciences. Nor is its formulation aimed at dividing in any sense whatsoever the full range of scientific investigations. What the definition does do, is to restrict the scope to a certain quantity of organised knowledge, this restriction being sufficiently justified by the fact that adult education will have to concentrate on this knowledge rather than on science in general; it cannot attempt to train scientific research workers.

Nor should such a definition be taken as expressing an epistemological bias relegating sociology, psychoanalysis, phenomenology, linguistics, philology, phonology, etc. outside the sphere of science. When studying these different disciplines, account must be taken of various "symbolic" factors, which cannot be apprehended by using only the logical or taxonomical methods employed exclusively in most natural sciences.

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NOTE 1: The contrast between "natural" and "symbolic" on which our definition is based may be clarified by taking the example of psychology. Man may be studied as a part of nature. The same methods would then be used as in the study of any other animal. As a result, however, the phenomenon of man (the object of the study) must be reduced until it corresponds exactly to the field in which the said methods may be applied. The elements reduced include language, irony, family relationships, etc., but only thus can one guarantee the validity of the scientific results which may be produced by these methods. Man, however, may also be studied as part of a so-called "symbolic" order. Thus defined, man is also reduced by restricting study to those elements which differentiate him from animals. There is, of course, no lack of links between the "symbolic" and the "natural" elements.

NOTE 2: Mathematics form a special case in so far as they basically involve perfecting abstract instruments. It is thus by virtue of their methodological qualities that they may be applied to the full range of natural sciences.

2. The present position of natural sciences in adult education

The specialists attending the study course unanimously deplored the insignificant position occupied by natural sciences in adult education curricula. Dr. Lendl, with the help of statistics which he described at the outset as unreliable in the sense that they included subjects outside the scope of our definition, suggested an estimate of between 3% and 30%. Natural sciences do not in fact appear to represent more than 1/10th of the curricula. There is no doubt a considerable number of successful activities in the field of vocational further education not recorded in these statistics. Such training courses are indeed first and foremost an essential requirement in the world of today, a necessity in guaranteeing high returns: the better a person's qualifications, the greater his profit earning capacity. The danger is that they encourage increased specialisation to the sole advantage of the business firm. Even if the individual derives some benefit from the point of view of promotion, earnings and, probably, personal satisfaction from his work, is this benefit not largely outweighed by the increased danger of being turned into an automaton?

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Indeed, to include vocational further education in the general concept of adult education could be described rather as a strategic move. Only when adult education is integrated into an all-embracing system of permanent education will vocational education be able to free itself from its present specific function of specialisation.

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It is true to say that natural sciences are at present still largely neglected in adult education courses. It does not however seem to be for want of having recognised the importance of their influence on man's environment. Perhaps it is bound up with the fact that the very subject matter of these sciences is difficult to communicate. Several experts are clearly aware of these difficulties, which will be dealt with in part 5 of this report.

3. The educational value of natural sciences

This important question was widely debated and received various answers according to whether the intrinsic value of the subject matter itself of these sciences was stressed or the methods of approaching that subject matter.

Both views agree, however, in stressing that men, and particularly adults, are ill-adapted to the world now being created by science. The adult these days is immersed in a world which he cannot recognise as his own, as the one inherited from his parents and formed by their modes of expression and thought. Today, the adult is fundamentally out of tune with his time, and this disharmony derives from the transformation of his environment by technology. Technology cannot be defined as merely furnishing artificial elements which may be understood simply by realising that they exist; on the contrary, it determines the new structures of our environment.

The advent of the supersonic jet has not only added a few hundred miles per hour to the speed of the propeller driven plane; it has caused a sort of shrinking of environmental space to the extent that what is "far", through becoming accessible in a few hours, is absorbed in what is "near", by virtue of this new accessibility.

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But language continues to make a semantic distinction between "far" and "near", based on the notion of inaccessibility (or accessibility). New terms will therefore have to be found to define this notion, which might otherwise become meaningless, thus creating in the human mind a sense of incompleteness and dissatisfaction. Only science education for adults can produce a re-definition of this old notion and thus ensure that the world is transformed to concord anew with the human mind which is unable to evolve at the pace imposed by science.

Although the two views mentioned above both reach the conclusion that adults are ill-adapted, they each have their own way of solving the problem.

The first attributed particular importance to the subject matter of natural sciences. The entire lecture by Dr. Rensch (Münster University) is characterised by this attitude. The following passages are quoted by way of illustration:

> "During the past few decades biological research has provided us with a large number of discoveries, which are highly important both for our view of the world and our practical lives and must, therefore, also be given due consideration in adult education. Many biological processes which at the beginning of this century could virtually only be regarded as miracles have since been analysed to such an extent that they are understood today as chains of causal events. In part, these cause-effect processes can even be traced as far as molecular structures. These are discoveries which, it may seem, are only the concern of biologists or those interested in biology. If we bear in mind, however, that our lives, too, can be understood, partly modified and directed by them in the future, then they become the immediate concern of every one of us. The effect on adult education is a positive one. When speaking to a large audience of laymen, especially within the framework of adult education institutes ("Volkshochschulen"), one repeatedly finds that everything relating to man arouses their particular interest.
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> What, then, are the recent biological discoveries that are of general importance? Important results have been obtained in virtually all branches of biology. Since by far the largest number of biological processes take place in the cells, mention should first of all be made of cytology, the science of cells. Owing to the

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invention of electronic microscopy, which provides an optical representation of what was previously invisible - even of macromolecular dimensions - and owing to the development of numerous ingenious biochemical methods, completely new insights can be gained. Today we know how much more complicated the structure of cells is than was previously assumed. Thus, the mitochondriae, which are present in all active cells and which under the conventional microscopes could be seen only as tiny fibres (threads) or grains, proved to be highly organised structures containing a large number of enzymes, which, organised in a certain way, control decisive biological processes. They are the power plants within the cells, so to speak. The respiratory enzymes, which use their supply of oxygen to release energy, become active. The energy is used to form phosphorus compounds, particularly adenosin triphosphoric acid, which constitutes the energy-supplying element in numerous vital functions. Today we also have much better information on the structure and functions of the carriers of the heredity factors, the chromosomes. We know the molecular structure of the hereditary substance, DNA, and are beginning to understand the process of identical reduplication and the synthesis of proteins with the help of other ribonucleic acids. The enzymes which are probably formed in this process trigger off a series of well-organised processes which result in the development of a living being from a fertilised germ cell. In this way, decisive biological processes, which even two decades ago were still something almost mystical, become intelligible ...

The same holds true for many other branches of biology. It has been possible to analyse at least the main aspects of the photosynthesis of plants, a process by which inorganic matter is transformed into organic matter and which ultimately constitutes the basis of practically all life. Along with hormones, substances were discovered that explain other miracles of life. These compounds, whose chemical structure is already partly known, largely determine the metabolism of living beings, their periods of growth and maturity and also trigger off the vital instincts - such as the reproductive drive and the maternal instinct - at the right time. The question of instincts, which seem so mysterious because it is through them that animals and to a certain extent men as well do the right

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thing without having to think, has also already been clarified in some of its essential points. It is known that nerve structures respond to specific signal stimuli, the so-called trigger stimuli, and start off adequate responses. The nervous systems used in this connection are only partly known, but again we are on the way towards an improved understanding of the cause-effect relationships. Decisive stages in the activities of the nerves, the sensory organs and the brain have been determined by means of surgical, electrophysiological and biochemical methods, which is, of course, extremely important for the understanding of how the mind works.

Completely new aspects were also discovered in the field of sexual research. It was found that the formation of the two sexes was not immediately connected with procreation but that the relationship is only a secondary one. What matters is that by the fertilisation of an egg cell by a sperm cell new combinations of the hereditary structures and consequently new variations of living beings are produced. Thus, there is always the possibility that under extreme conditions of life that occur again and again - such as extreme cold, heat or drought, epidemics or new enemies - at least some resistant forms survive and ensure the continuation of a species. Natural selection, after all, is much more severe than was thought for a long time. The extremely high extermination rates with all types of animals and plants (frequently more than 99% of the off-spring perish in the struggle for life before they themselves have reached sexual maturity), clearly demonstrate the severity of natural selection. The very fact that sexuality has been maintained both in plants and animals throughout their phylogeny extending over millions of years, although non-sexual reproduction is also possible, is proof of the extraordinary importance of the new combinations of genes it permits.

Furthermore, we begin to understand something about the causality of the individual process of development, i.e. the process of differentiation from the germ cell or embryonnic stage to a grown-up living being. The decisive factor in this context was the recognition of the role played by the biochemical structure of the egg wall in the initial processes of differentiation. Numerous experiments have revealed

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the interplay between autonomous differentiation and the effects of neighbouring tissues produced by chemical and external influences.

Evolution research has also presented us with fascinating results. We know the factors that have led to a transformation of species of animals and plants, a process in which new combinations of genes, mutations, flow of genes, frequency fluctuations of genes within populations, selection and isolation, all worked together to a different extent in each case. It was possible to formulate many phylogenetic laws and constants. We are also comparatively well acquainted with the stages in the development of man.

All these new discoveries, of which I could only mention some of the most important ones, are not only of theoretical interest. They also play an important role in practical life. Lawyers, teachers and all those in a leading position must know how far-reaching an influence hormonal disorders may have on human behaviour. They must have an idea of nerve and brain processes in order to judge human failings correctly. Everybody must be familiar with the nature of heredity, which so decisively determines his life and the lives of his children.

For adult education purposes, therefore, it is important to present biological problems in their relation to man, in order to stimulate interest. Even if one wishes to discuss the physiological processes that take place in a plant cell, one should not fail to point out the basic similarity to human cells.

By way of giving an example of an issue that is of special importance, I would like to discuss briefly the phylogeny of man and man's special position among living beings. This topic is always a fascinating one and is well suited to illustrate the present conflicts and future dangers that mankind is exposed to unless it pays due consideration to the biological principles of life.

A topic of special interest is the question as to how it was possible for one branch of the ape family to develop into man. From the anatomical, histological and physiological viewpoint man hardly differs from the apes, especially the anthropoid apes. Under the miscroscope the cells of a chimpanzee - irrespective of

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whether they are gland, muscle or brain cells - look exactly like human cells. The functions of the cells, too, are basically the same. The number and arrangement of the bones are the same in chimpanzees and men, it is only the proportions that are different. The frontal brain of apes, too, has many convolutions and is divided into similar functional areas as the human brain. Thus, we can say that from the morphological, anatomical and physiological point of view it is only quantitative differences that distinguish us from the most highly developed animals. But how could we obtain our unique special position? A special position which, no doubt, has raised us to a fundamentally different higher level of life. Mankind has developed a highly differentiated civilisation, it has developed scientific, artistic and religious values, lives in accordance with established rules and ideals, controls the earth with its technology and is able to scan the most distant worlds or penetrate the atom. If we want to find out how such a development could come about, we must first of all make a survey of our phylogenetic ancestors.

These considerations lead us to enquire into the origin of life on our planet. Until a few decades ago this question could only be answered with "ignoramus, ignorabimus". Today we have come a little closer to its solution. In 1953 S.L. Miller succeeded in producing some complicated compounds (including several amino acids, the components of proteins, as well as some other vital organic compounds) by means of high-voltage electric discharges in an environment resembling the primary atmosphere of the earth, i.e. an atmosphere consisting of hydrogen, methane and ammonia. Further experiments carried out under such pre-biological conditions have shown that almost all chemical pre-requisites for biological processes - including the components of the nucleic acids, which are so highly important for heredity - can be produced in such a way. The sources of energy that were used included the short-wave rays (UV) or the high temperatures typical of our planet in its original state. By pouring amino-acid over lava (at a temperature of 200°), Fox and his collaborators succeeded in producing so-called proteinoid drops, tiny protein-like, highly stable compounds. It

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was also possible to demonstrate various other possibilities of protein synthesis. The Russian scientist A.I. Oparin produced so-called coacervate drops containing the primary vital substances, proteins and nucleic acids. Of course, it is still a long way from these compounds to the origin of even the most primitive cell, but we can already say with some degree of probability that the first living beings gradually developed from inanimate nature.

The close relationship of all living beings, including man, is also reflected in the highly similar structure of the cells of which all organisms are composed. All cells with a normal function consist of cytoplasm as the basic substance, chromosomes as the carriers of hereditary material, mitochondriae or their precursors as the "power plants" and a cell membrane that is responsible for the absorption or excretion of certain substances. The close relationship of all living beings is further illustrated by the fact that the structure of the hereditary substance, deoxyribonucleic acid, is the same in all organisms. The discovery of the chemical structure of these extremely long thread-like molecules may perhaps be called the most important biological discovery of our century. The DNA molecules consist of two helical strands, wound around each other, in which phosphate and sugar groups (pentose) alternate with each other. The two ribbons are connected by two pairs of bases consisting of adenine, thymine, cytosine and guanine, which are held together by hydrogen bonds. The differences in the hereditary substance of living beings are due to the alternation of the two base pairs along the molecular thread. Replication of the double-helix molecule is possible by "unzipping" along the hydrogen bonds; each strand complements the other with its individual components in the nucleus, i.e. the corresponding nucleotides consisting of a phosphate group, a sugar group and a base each. This explains the secret of the identity of offspring and the secret of heredity on its molecular basis. The transfer of genetic information from the DNA molecule to the cell is effected as follows: A complementary ribonucleic acid, the so-called messenger ribonucleic acid, is formed; it passes from the nucleus into the cytoplasm and becomes associated with the ribosomes where proteins - or first of all enzymes - are

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synthesised with the help of other amino-acids supplying nucleic acids. Whether the hereditary substance, which always consists of the same components, results in the development of a cockchafer, a trout or a man will first of all only depend on the base sequence of the DNA as well as on the presence of the chemical compounds necessary for protein synthesis in the ribosomes and for the formation of tissue.

The discovery of these relationships is a most thrilling discovery which clearly shows us the uniform character of all forms of life and the intimate connection between man and the other living beings. This is extremely important for the biological view of life to be taught in adult education classes, particularly since it demonstrates that these molecular mechanisms conveying genetic information also determine hereditary intellectual abilities. Of course, these highly complicated processes could only be outlined in a very simple, commonly intelligible form. Presented in this form, the subject will not be too difficult for lectures at "folk high schools", particularly if these lectures can be illustrated by slides. ..."

The remarkable fact about this lecture is the clear way it highlights the answers provided by science to questions which the human mind has always pondered. It is for this reason that the author states, very rightly, that "everything relating to man arouses particular interest", a statement borne out by the following quotation from the lecture by Dr. Fischer (Giessen University): "With reference to natural sciences in present-day adult education, the question is not so much to explain a subject in depth, but rather to clarify its meaning for the individual and his way of life".

This subjective interest exists because the questions answered above are rooted in the very structures of our common pool of speech and thought.

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The second viewpoint had a greater following at the St. Wolfgang course. In contrast to the previous one, it stresses the value of scientific method. Three lecturers emphasised this aspect in particular, Prof. Eder (Giessen), Prof. Gerlach (Munich) and Mr. Rainer Biemel (Paris).

Man adapts to the modern world by learning to think in new ways, by acquiring new patterns of thought. There is no longer any branch of knowledge, especially in science, that claims to represent absolute truth. Knowledge itself would be called in question if dissociated from the analytical method which produced it. On this very point, Dr. Eder's lecture is particularly revealing and proves that even scientists are developing a new pedagogical sense:

> "By a physical view of the world we no longer mean - unlike the 19th century - a precise, exact replica of the universe in the human imagination. We obtain physical knowledge by certain methods of thought, and scientific results are meaningful in relation to the methods by which they were obtained. Thus, the physical view of the world rather serves to prepare the way in nature, with ways of thought and methods being a special approach. A physical theory of life is not a rigid framework but rather a starting-point for an expedition that is to familiarise us with the world.

In terms of space, the physical world ranges from a length of 10^{-17} m in structural analyses of elementary particles in high-energy physics to a length of 10^{26} m in linear measurements of the universe. In both these extreme cases it is not a matter of our actually being able to measure the length of elementary particles or galaxies; in the case of elementary particles we rather extend our experience of contact obtained from the impact on macroscopic balls to the high-energy impact on elementary particles in submicroscopic dimensions. In the second case we transfer our perspective sense of space based on seeing trees along an avenue to the brightness and frequency of the galaxies and from this deduce the spatial structure of the universe. Physics enhances the sensory perceptions of man by many orders of magnitude, so to speak. This is directly done with the help of microscopes and telescopes, which increase the apparent size of an object by several thousands of times. Indirectly, this intensification is brought about by any physical research method. When an atomic nucleus, for example, gives out 10^{21} sound vibrations per second, we cannot hear

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the sound but can only observe the effect of the gamma radiation emitted by this nucleus in a solid body. We also know that nuclear radiation has only a very short range and ceases to be effective when the distance of a proton or neutron from the atomic nucleus is greater than some 10^{-15} m. This knowledge cannot be obtained by measurement but only be counting how many neutrons of a neutron beam pass a nucleus without interruption and how many are deflected to a greater or lesser extent. The longer the range, the more neutrons are deflected. Radio and television extend our acoustic and optic capacity over continents and even as far as the moon or the planets. Radio-astronomy has greatly expanded our knowledge of our galaxy and the universe. Visible light is absorbed by the gas and dust clouds of the galaxy, whereas radio waves provide us with information on the location, density and movement of the gases. Directly and indirectly man obtains an insight into the universe and thus becomes familiar with it. By this increase in perceptual possibilities, human nature, in a sense, is unlimited from the physical viewpoint.

The relation between physical knowledge and research method may seem to be subjective. Physical knowledge, however, is objective especially in that it can be accurately reproduced by any man at any time. Nevertheless, it is generally essential to state the research method, since certain properties such as the size and colour of an atomic nucleus are not a priori meaningful but become meaningful only in a specific physical context."

Today, the validity of a scientific discovery or conclusion depends more on the methods by which it may be justified than on whether it actually corresponds to "reality". The reason, for example, why astrological systems based on the signs of the zodiac are denied scientific recognition is not because they do not correspond to reality (statistics show that there is some "truth" in astrology), but rather because the methods on which the principles of these systems are based are so obscure and complicated.

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As Professor Eder emphasised, what guarantees the objectivity of scientific results is the possibility of obtaining identical results at any time or place, thanks to an exhaustive explanation of the method employed, the conditions under which the experiment was carried out and the functioning of the apparatus used. Scientific objectivity depends essentially on the instrument employed (whether it be a concept or a piece of apparatus). As Bachelard affirms: "The true principle of identity in all applied sciences rests on identity of apparatus" (Activité rationnaliste de la Physique contemporaine", page 5). Objectivity is certainly based on this principle of identity.

Similarly, the educational value of scientific method was brought out clearly by Professor Gerlach:

> "What is scientific knowledge? Why do we not speak of information or results? Because it means something that results from the knowledge of nature, from the results of scientific research only when this knowledge is processed according to the rational principles of thought characteristic of the natural sciences: into knowledge about the essence of nature, about the relationships of natural processes and their underlying laws, about the primary elements which constitute the basis of natural phenomena.
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> Therefore, the possibilities of rendering this process of cognition accessible to the general public shall be presented here. Whether such possibilities exist or not, however, always depends on three entirely different prerequisites: whether this process of cognition can be popularised at all and whether there is the ability and the readiness to accept it. These prerequisites at the same time constitute the limiting factors. The possibilities, however, are also limited by external reasons, for example the time available. This is only a secondary consideration for us. In the same way we will exclude from the tasks of adult education anything that is tied to a specific purpose, i.e. any extended or more specialised vocational training."

The aim here is to render the scientific method accessible to adults. Rather than the subject matter itself, it is the way of comprehending it that counts. Understanding methods is more important than knowing facts: education for adults should be entirely centred around this basic principle.

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To quote another striking remark by the same author:

> "Here we find that people usually do not understand what they know. We are used to nature as it is, and unfortunately people often do not feel the need to understand the things that they are used to."

... for, to understand, we must reject common sense notions and the series of "obvious truths" firmly rooted in our current habits of speech.

This same viewpoint is further illustrated in the lecture by Mr. Biemel. The essential reason why man is not adapted is because, owing to the speed at which the world is developing, he must face up more and more to new situations and solve problems without understanding the facts involved. Confronted by these situations, there are two possible solutions:

- either to reduce the new to the level of the familiar; by affecting the given facts, this reduction also affects the solution; this is true, for example, in the well-known phenomenon of routine where all new problems are systematically "reduced", since their solution depends entirely on the established practices used to solve everyday problems. The quality of the solutions arrived at automatically drops and the gap between such solutions and those demanded by new problems widens more and more;

- or to acquire a technique enabling man to be equal to the new aspects of any problem, as Mr. Biemel rightly states:

> "If we are convinced that it is not our memory that will be of decisive importance in the future but rather the ability to master completely new situations, to cope with the unknown, we must give absolute priority to the development of techniques, imaginative thought and effective intelligence in adult education methods."

Modern mathematics are the most general and useful illustration of these techniques, as Mr. Biemel clearly demonstrated in his lecture.

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4. The question of motivation

This question was widely discussed at the study course. To quote Dr. Lendl's classification:

"The inclusion of natural science subjects into adult education programmes is based on three different motivations on the part of the audience.

1. The first group of people is interested in acquiring a thorough knowledge of a specific branch - e.g. botany, biology, mathematics, physics, astronomy, etc. They desire to work systematically, perhaps even to carry out their own experiments. In all countries, such groups find it possible to satisfy their interests at adult education institutes. The forms of instruction vary greatly, reaching from university courses and loose study groups to systematic series of lectures. This undoubtedly valuable form of adult education constitutes a highly specialised leisure activity, which greatly contributes to the development of the personality and to the raising of the cultural standard. However, it is private in nature and determined by individual interests.

2. There is a second group of people, whose interests are no longer of a private nature: they wish to familiarise themselves with certain issues of modern life and thought, e.g. medicine and hygiene; problems concerning the maintenance of biological health; man's natural environment (water, air, soil, plants), which is a prominent social problem today; issues of topical interest such as space travel, nuclear physics, heart surgery, etc. Adult education has always regarded it as its task to provide this knowledge with a full sense of responsibility for the individual and society, i.e. on a sound scientific basis without any manipulatory intentions. In this way, it accepts an educational task of deep social significance.

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3. There is a third group, which is of a great social as well as individual importance. The people in this group aim at furthering their vocational qualifications, becoming informed about progress in a specific field, training for a new profession as well as perfecting their fundamental school and professional education. The acquisition of new knowledge, insight and skills is of paramount importance for the efficiency of our national economies and for the development of our national cultures. New possibilities open up before the better informed and better educated person: improvement of his social and professional position, a higher income and, it is to be hoped, greater pleasure and success in his work, as well as fuller, more active participation in social life. This new situation also affects the non-professional activities of an individual as well as his family and environment."

These three types of motivation do not exhaust all the possibilities.

In his lecture, Mr. Biemel mentioned a motivation which derives from the particular situation in which parents of school children find themselves:

"The headmistress realised, however, that she had to inform the parents about the curriculum reform, which consisted in teaching mathematics instead of arithmetic, and she asked me whether I was willing to do this. I agreed, and it was decided to hold a parents' meeting on Saturday evening.

When I arrived on the Saturday in question, the headmistress explained to me that she had a bad conscience for having asked me to come, since probably only few parents would come owing to the bad weather. I tried to reassure her and told her that even if only three or four people came the meeting would still have been worthwhile. Actually more than 300 people had come by 8 o'clock - far too many for the relatively small lecture-room. I tried to show the parents that it was only natural that in 1964 their children should not be presented the same material that they had been given 20 or 30 years ago in arithmetic classes, particularly since it had been so unsuitable that many of them shuddered when thinking back to their own mathematics lessons as children.

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Simple as this argument sounds, it is difficult for the parents to accept. I remember that at another meeting, which was also held to inform the parents about the teaching of mathematics instead of arithmetic in primary school, I began my report by telling the parents that four astronauts had successfully landed on the moon. This sensational announcement was accepted almost as a matter of course. But when I tried to explain later on that it could no longer be the task of the primary schools to set up calculating machines in the children's heads, the parents were sceptical and critical, since - at a time in which so much is changing - they want to satisfy their need for security by clinging to the fact that $2 + 3 = 5$ is a truth that will outlive the world. It is not only the need for security, however, that comes into play here but also the authoritative position of the parents vis-à-vis the children, which implies that - at least if the children are young - the parents must know more than the children. Otherwise they feel overwhelmed with questions and - exactly like the teachers - believe that their authority is being questioned.

It must be said that, of the parents concerned, only a small percentage are qualified to assume their role as educators."

The point at issue is parents' desire to keep in touch with what their children are studying in spite of radical changes in subject matter. Adults already feel to some degree unable to communicate with their children, and this feeling is reinforced by the impression of losing their authority. Parents' authority is traditionally based on their greater fund of knowledge. By acquiring knowledge not shared by their parents, children escape parental authority and control. This type of motivation is based on the relationship between knowledge and power, whereas the types referred to by Dr. Lendl depend more on a relationship between knowledge and "value", prestige being, however, one of the basic values of modern societies (as the sociologists Wright Mills and David Riesman have clearly demonstrated).

As for motivations centred on professional interests, they could much more easily be defined by reference to the individual's aims in following a science course than by referring in any way to the knowledge itself. In the vocational sphere, science is viewed as a means to certain ends rather than as an end in itself.

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Dr. Gerlach brought out the importance of technology in motivating various groups:

> "In our time there is something with which all people come into daily contact, something that arouses their interest in one form or another: technological gadgets. These all function according to physical laws, and since the knowledge of the interplay of their different parts arouses the curiosity and the play instinct of one person and seems useful to another person who wishes to use or repair them, everyday technology is an ideal starting point for one essential type of instruction in physics: it is a stimulus for asking scientific questions, about whose value there cannot be any doubt."

Dr. Eder stresses the same point:

> "Constant changes in man's environment are not harmful so long as he fully understands the properties of the materials and the principles of the technology he uses. Technical products as such are neither more nor less familiar than natural products. They do, however, become strange and threatening, unless we familiarise ourselves with them in time through practice and theoretical education."
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> (...)
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> "Everyone today therefore needs a greater amount of natural science education (...). The alienation of man from his environment and the impression of being lost in the world of automation are the consequence of insufficient natural science education."

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Certain psychological factors, however, prevent the individual from satisfying directly and spontaneously these motivated desires. Very important among these is the <u>need for security</u>, reinforced by <u>resistance to change</u>.

For learning often necessitates the arduous task of calling in question the very knowledge one has acquired from long experience of life. Natural sciences are particularly difficult to teach because their subject matter is the world where people

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are living and on which they already have their own ideas, opinions and beliefs. The world described by the natural sciences is governed by universal and abstract laws, whereas this same world is at the same time governed by the very special laws of human subjectivity. Natural sciences thus very often unsettle ideas, opinions and beliefs to replace them by knowledge which is often too abstract, or in any case outside the sphere of personal experience and frequently, for that very reason, useless. And yet it is the very abstract nature of this knowledge which guarantees its validity, while making it unpopular and unattractive. What indeed can surpass the reality and certainty of personal experience? Why bother with a system for classifying mushrooms based exclusively on their method of reproduction when it is so simple to distinguish the good ones from the bad with a silver teaspoon?

This brings us to the perennial epistemological problem of the relationship between subjective and objective knowledge, to which we shall return shortly.

5. Obstacles preventing the wide dissemination of scientific knowledge

The lectures at St. Wolfgang fully appreciated the importance of this problem. Some, however, stressed those obstacles which might be described as depending on institutions while others emphasised the purely epistemological ones.

(a) Obstacles depending on institutions

Adult education suffers at present from a lack of laboratories, organising bodies, qualified teachers, etc. Appropriate teaching methods are required, in which knowledge is not passed on by means of specialist lectures. As emphasised above, it is what the adult has learned by contact with reality that must be called in question, and the same process will allow his knowledge to be renewed and perfected.

The following remark by Dr. Fischer may be noted:

> "An adequate representation of these fields presupposes adequate buildings and rooms, adequate equipment and, consequently, adequate financial means, provided that the traditional institutions of adult education are qualified at all."

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(b) Epistemological obstacles proper

All the lecturers agree that science education for adults is possible in principle. Similarly, they all warn the teachers or the organising bodies concerned against the dangers of over-simplification, incomprehension (or rather misunderstanding), and of interpretation, ... inherent in such a form of education. In fact this problem is dealt with only superficially in the lectures.

In spite of that, it is possible to draw attention to certain of these obstacles:

- Abstraction. All science is abstract in the sense that our actual, concrete experience of the world is resolutely excluded from any scientific investigations. But the very educational value of natural sciences depends fundamentally on the changes that instruction in these branches of science may produce in man's subjective experience of the world. This contradiction may only exist on a purely rational plane but one cannot afford to ignore it.

This abstract side to science was also pointed out by Dr. Gerlach:

> "A law of nature cannot be deduced from a concrete example; it always contains an abstraction.
>
> The more deeply one wishes to analyse a natural phenomenon, the more one has to ignore what is perceived by the sensory organs.
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> We have said, however, that all natural phenomena are based on laws of nature. If we started the teaching of physics by making children learn the basic rules of that science, their significance could not be understood. This pedagogical error is often made at lower and higher school levels - with the result that an internal defensive attitude is produced, since the question 'why?', 'why should I learn this?' has at first to remain unanswered.
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> Adults will feel more dissatisfaction than younger people, since there is no appeal to their emotions and feelings, as they would prefer. Making people start by studying basic laws gives rise to a second difficulty: if the explanation of a process is followed by the process itself, it often happens, particularly with so-called simple

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processes, that the law does not seem to be valid. Take for instance Galileo's famous law of falling bodies: there is no actual case in nature in which it is valid! And yet, it is a basic law of nature!

In teaching natural science we must not forget how many detours and errors there were until a fundamental law of science was discovered; and somehow the individual student has to follow the same path that generations before him had to follow before they came to understand things."

Here stress is laid on the difficulties inherent in the abstract nature of scientific knowledge. It is true, as Prof. Eder states, that "there are no concepts which are concrete or abstract in themselves" (see below page 28). But his argument, based on the fact that "newly introduced concepts are always abstract" whereas "old and familiar concepts, whose meaning can be demonstrated by numerous phenomena, are always concrete", is not very convincing. The real issue is whether the transition from abstract to concrete, by having to stand the test of actual phenomena, does not rob a concept of its scientific status, and, by that very fact, of its educational value which depends, as the same author so rightly pointed out, more on the methods of thought, the path followed, than on the results obtained. "Atom" and "energy" have no doubt become very concrete notions, but after having been disseminated excessively, popularised haphazardly and illustrated schematically for over half a century, have they retained, in the minds of those who employ them as concrete terms, their strictly scientific meaning?

Everyone understands in very concrete terms the concept of weight. But as soon as one attempts to illustrate the law by rational argument, one realises what an abstract notion it really is.

- Method. Advances in natural sciences are made by applying certain methods of thought which are peculiar in that they often run counter to the methods of thought implicit in everyday language. Science contradicts common sense. It destroys the most widely accepted truths, disrupts habits of thought, demystifies the most firmly established beliefs. Herein lies, moreover, its essential educational value. This perpetual doubting of patent facts may be considered in many respects as a struggle waged by scientists against their own habits of thought rooted in their linguistic habits. The special

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quality of the scientist is to distrust what he says; truths which emerge spontaneously as he talks, he finds suspect. In a word, his attitude is critical. The commonplace truth is one which is self-evident, the mere reflection in words of some phenomenon. Its degree of truth depends on equating word with object. But demonstration is the only way to prove its accuracy, its scientific truth which is guaranteed by a method whose one aim is its "self-transparency", by the fact that anyone, at any time, may apply it and achieve the same results (see Hesserl: "Formal and Transcendental Logic").

- Terminology. Science makes use of very specialised terminology, but the necessity for this is no longer disputed. It is particularly difficult to penetrate this terminology, to the extent that it cannot be translated into simple terms. Although the term "ecchymosis" means exactly the same as bruise, there is in fact something lacking in the former term which exists in the latter: namely, the ideas of pain, blows, etc., which are closely associated with the expression "bruise".

The epistemological obstacles exposed above are in fact only relevant where science education for adults might be likened to a sort of popularisation programme which, even if systematically organised, would probably not produce the hoped for results.

6. Types of science education for adults

In dealing with the educational value of natural sciences we claim to have discovered two distinct viewpoints, one laying more weight on the specific subject matter of these branches of science, the other on methods.

This distinction may be justified by a more fundamental one between a problem and its solution. In other words, science is at one and the same time:

- a way of stating problems,

- a collection of solutions to these problems.

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The manner of stating problems corresponds to the scientific activity. The collection of solutions may be considered as representing the body of knowledge resulting from that activity. Acquiring the ability to state problems scientifically may be described as "initiation". Presenting the solution science offers to these problems may be described as "popularisation".

The problems themselves have in fact always existed. The only possible variables are a manner of stating them and their solution, with the latter obviously depending on the former. Genuine popularisation, that is, the kind which really attempts to convey a certain amount of objective knowledge, must of course indicate how a particular discovery has been made, by what experimental processes it has been arrived at, by what deductive methods it has been substantiated. This kind of popularisation is, in our opinion, very rare, for it implies a certain asceticism and sustained effort on the part of those at whom it is aimed. In this sense of the word, moreover, it would seem to belong rather to the process of initiation defined above. The usual kind of popularisation text, as found in newspapers and magazines for example, is a mixture of morals, ethics, religion, technology, utility, profitability, psychology, etc., in which scientific facts are subjected to evaluation, extrapolation, simplification, generalisation. A profusion of metaphors, metonymies and analogies burden the scientific text with the imprecise terms typical of everyday language. In order to prove this, it is enough to estimate the significance given to numbers. In a piece of scientific reasoning, the precision of a number is justified by the fact that it constitutes an essential step in the argument. In literature popularising science, a number is usually just an illustration in figures of some affirmation or other. It is the trade mark which lends the text a "scientific flavour".

It is not our present task, however, to pass judgment on the popularisation of science. It exists, and although its express aim of transmitting knowledge is rarely attained, it has nonetheless the essential function of integrating the achievements of science into our daily lives.

Science allows discoveries to be made, truths to be established, processes of thought to be initiated, techniques to be invented, etc. These various facets of scientific activity have repercussions on our daily life and subjective experience. It is important that mankind and especially adults should be capable of adapting themselves to the new world which is coming into existence. This adaptation depends on two essential prerequisites: -

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(1) Giving adults the chance to review critically the knowledge they possess, i.e., to use Carl Rogers' term "to teach them to learn again".

(2) Supplying them with answers they can easily assimilate, i.e., which do not contradict the basic structures of their everyday thought.

Since these two requirements are complementary, they could be covered by popularisation in all its forms.

The accent will have to be put on the subject matter of science, the most concrete aspects of its discoveries, thus allowing adults to readjust continuously their vision of the world to keep in step with scientific discoveries.

It is not necessary to penetrate the innermost secrets of a computer in order to be able to use one. Nor is it necessary to grasp every step in the theory of evolution to be able to distinguish man from other animals. A few pertinent distinctions, easy to express in everyday language, suffice to give a clear idea of the differences between man and the most highly developed ape.

Indeed, the process involved in this aspect of popularisation might be defined as the adoption into everyday language of certain scientific concepts.

This fact moreover has inspired the idea of using systematically mass media and particularly television (see the lecture by Lawrence Bragg).

The following extracts from Professor Eder's lecture are a good illustration of this need:

"<u>Survey of the results</u>

> . . . A survey of topical scientific results can be obtained from a number of technical books such as 'Kosmos-Naturführer', 'Fischer Lexikon' and other series, as well as from journals such as the 'Scientific American', in which scientists report on the results of their research activities in articles that are illustrated by numerous illustrations and diagrams. These publications are devoted to the most recent discoveries and to scientists who are generally still

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unknown to the layman, which is in contrast to a German journal which publishes articles by famous personalities who were actively engaged in research work some forty years ago.

Selection of material and system

Adult education should be subdivided according to professional groups. In the selection of teaching topics, therefore, those subjects should be given preference that are closest to the respective professional interests and are thus easiest to approach. Subsequently, the topics should be increasingly extended until finally the entire field of the natural sciences is covered. All this refers to systematic courses in the framework of day and evening classes, regular weekend courses or study groups. The educational value of single lectures, or series of lectures held at intervals of two weeks is doubtful. First of all, education can be imparted only if there is some basis; in a single lecture, however, time is far too short. Second, knowledge will be assimilated and retained only if it can be brought alive in one form or another, for which again there is no opportunity in single lectures. Third, the educational levels of the audience in single lectures are too different to permit a thorough discussion of the problems. Fourth, the subject-matter of single lectures must appeal to the public and thus the real aims of education tend to be pushed aside. It seems that single lectures should be restricted to festive occasions and aesthetic associations.

Possibilities of popularisation

In relation to physics the question of the possibilities of popularisation is particularly topical, since there are numerous popular presentations of the theory of relativity or the quantum theory, which are generally incorrect but intelligible. The difficulties of popularisation probably do not lie in the subject-matter as such but are rather due to the fact that originally physics research was not sufficiently detached from its own results. Today, the fundamental relationships in modern physics are much better understood than at the time when they were discovered. For this reason it has become easier to describe and discuss scientific results independently of their underlying mathematical formulation.

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Theoretical physics, in particular, may seem to be inseparable from its underlying mathematical methods, so that any non-mathematical statement would necessarily be wrong. This is not true, however, since theoretical physics is not a mathematical discipline. It uses mathematics only for the sake of a precise, compact, brief and clear formulation of facts. For this reason it must also be possible to formulate the results as factual statements. The question as to whether the volume of the universe is finite or infinite will preferably be tackled within the framework of the mathematical formalism of gravitation theory. Nevertheless, the result can be formulated in simple terms: let us think of the volume of the universe as being successively filled with cubes with an edge length of one light-year each; if this process is complete after a finite number of steps, the volume is finite; if not, it is infinite.

Another doubt as to the possibilities of popularisation relates to the abstractness of the concepts used in modern physics. Against this it can be argued that there are no concepts which are concrete or abstract in themselves. Newly introduced concepts are always abstract. Old and familiar concepts, whose meaning can be demonstrated by a great many phenomena, are always concrete. The clarity of a given concept is nothing but the sum total of the phenomena associated with it. At the turn of the century concepts like 'atom', 'energy' or 'impulse' were still very abstract and partly controversial. Today, they are clear even to non-physicists. Gradually, every concept that holds a central place in the natural sciences becomes concrete.

In principle, the question of the possibility of popularisation can be answered in the affirmative, though there is still much that remains to be done in this direction.

Extension to a wider public

The share of the natural sciences (particularly that of physics) in adult education is very modest at present; however, the figures are not very representative, since, on the one hand, the prevailing practice of single lectures is not particularly suited for natural science instruction and since, on the other hand, only a minority of the working population participates in adult education programmes.

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It is necessary to find suitable forms of schooling. Residential courses in 'folk high schools', as they exist in the Scandinavian countries, are probably well suited to raise adult education beyond the level of an aesthetic leisure activity and to extend education to communities with an unfavourable geographical location.

Above all, the scope of adult education has to be expanded. This can easily be done by linking it with continued vocational training."

The possibilities of popularising science are clearly confirmed here, and even when Dr. Eder speaks of imparting scientific knowledge by lecture series, the method recommended never loses touch with reality.

This context of reality is certainly necessary if the layman is to understand the phenomena revealed by science. But it does involve certain dangers.

To quote one example, there is the common danger of extrapolation. Why does it happen that the extrapolation of certain scientific results may be abused?

Since such results are the product of scientific reasoning, they imply certain inherent limitations. To transfer these results together with the reasoning which produce them into everyday language deprives them of their specificity in the sense that the semantic structures of everyday language differ from those of scientific language. To evaluate a scientific result at its true value, it is necessary to take account of how it was obtained, the extent to which it supplements or contradicts some other result obtained by different ways, what conclusions may be drawn while respecting the methodological restrictions of the premises, etc.

Once transferred into everyday language, however, the result can no longer be subjected to any methodological control. It is henceforth defined with reference to criteria which have nothing to do with scientific reasoning: moral, economical, political, topical, social, psychological, etc. It is absorbed into linguistic structures which are just as apt for shaping the processes of imaginative musings as those of philosophical or political thought. Extrapolation originates

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in explaining a result with the help of another kind of reasoning, which employs semantic lines of argument other than the scientific method. A result which bases its proof on facts from everyday reality contravenes the elementary rules of method which require the sense of an argument to depend on logical associations within its own sphere of reference.

Scientific language is above all abstract and formal. Formalisation is its dominant characteristic, and it is not without cause that natural science research workers strive at all cost (and sometimes, apparently, even at the expense of the most elementary common sense) to achieve a certain formalism (in this connection see "Cahiers pour l'Analyse" No. 10, "La formalisation", Editions du Seuil).

By stressing the abstract nature of natural sciences, the part played by hypothesis and its verification, the universality of the laws of nature, the importance of dedutive reasoning, the logical aspect of research, etc., Dr. Gerlach has highlighted the first prerequisite which we mentioned: "to teach people to learn again".

The educational value of natural sciences consequently resides in the fact that they may procure for man new methods of comprehending the world.

To acquire this method of thought is one of the most difficult aspects of science for it is the one which demands most effort from those seeking initiation. Scientific method may indeed be defined by its semantic "non-ambiguity" and by the fact that, in order to make use of it, we must abandon or at least temporarily suspend the natural course of those thoughts which are determined by our linguistic habits. Are adults prepared to furnish this effort of "disengagement of the self", of one's own language and simultaneously one's thought processes? The experiment of Mr. Biemel may be quoted in order to reply in part to this question:

> "I directed the work together with three other teachers. Every Monday night we met in the mathematics room where the children worked during the day. The parents could use the mathematics laboratory, which basically consisted of the logical blocks by Dienes, his multi-base material and his algebra material. I would like to show you briefly these different materials, although it would have been preferable for you to handle them yourselves.

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Slides: Logical blocks,
Multi-base blocks,
Algebra material.

Approx. 20 minutes

Why must adult people be given the chance to comprehend things by manipulating them? Simply because this is how the process of learning really takes place. This is clearly reflected in the various languages: when taking the French words 'comprendre' or 'apprendre', we can see that the root is always 'prendre', i.e. 'to take'. To comprehend, therefore, actually means 'to take together', to learn things by grasping them. Similarly, the German word 'Begriff' is derived from 'greifen': to grasp. We grasp things with our hands and not with our eyes or ears, and when we have understood something, we have "grasped" it. A Chinese proverb, which may be thousands of years old, points in the same direction. It says, "I hear and forget, I see and remember, I grasp and understand".

If we wanted to put this methodological knowledge into practice in adult education, we would have to do away with lectures like the one I am giving now and replace them by active working sessions. It would no doubt be possible to read and study in advance the texts which prepare the way for practical sessions, but true understanding will come only in practical seminars.

One may have different opinions on the revolt of the university students in so many countries, but there is no doubt that the method of teaching by lectures really belongs to the past. In adult education this knowledge of the learning process should be put into practice without fail.
(...)
Dienes found that what Piaget observed in children's learning process was also valid to a certain extent when an adult discovered or learned something new. This constitutes a methodological realisation which adult education would of course have to take into account. A factor in Dienes' explanations that appears rather strange at first is the new concept of play. Not only teachers but adults in general are opposed to play because they confuse play with amusement and fail to realise its genuine importance.

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Let us briefly look at the playing child. A child can repeat over and over again a word that he has just learned and in doing so he can almost playfully consolidate something he has acquired. A child can spend hours building castles in the sand and thus develop and control his spatial perception. In the same way, a child can spend hours playing with his box of bricks - place brick upon brick, destroy what he has built and start afresh. Nobody observing a child at play will deny the importance of this activity, which constitutes a genuine achievement, for his physical and psychological development.

As we know, school means an end to play. It is not that suddently, at the age of 6 or 7, the child no longer needs to play in order to learn, but rather because school has been created by society to shape and model - one might even say to produce - adults according to its needs; besides, it is not the aim of the schools to develop all the latent abilities of a child. (...) As is well known, the great creative personalities were often in the fortunate position of not having to undergo primary school drills. They thus preserved their creative faculties, their sense of discovery, of play and research. (Cf. the biography of Evariste Galois and the autobiography of Norbert Wiener.)

When looking at the pedagogical problems of adult education, however, we must bear in mind that the people we meet have been conditioned and drilled and that, in the first place, they expect to be subjected to the same treatment again. This explains, for example, the success of programming and programming machines, which are a perfection of the method of drills employed in the primary schools - no matter whether we are speaking of linear programming according to Skinner or the multiple choice branching method developed by Crowder. However, if we want adult people to take pleasure in learning as little children do, we must give them an opportunity to rediscover the sense of learning through play. Of course, this is very difficult, particularly because of the generally negative attitude towards play and insufficient knowledge of the most recent results of fundamental research in this field.

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> In the 40 mathematics clubs for parents that exist in France we obtain successful results only if we succeed in making the grown-ups play, in making them relive the process of learning of their earliest childhood, so to speak."

There should be no illusions about the meaning of Biemel's experiment. The play activities which he describes and recommends in fact represent the ideal way of understanding abstract notions. The material presented is formal. Only the matter of which it is composed is tangible: wood, plastic, metal, etc.; but the activities involved deal with forms, in this instance, the logical blocks of Dienes.

This material may be combined in certain ways determined by the forms of the different pieces themselves. These forms and shapes have the very same function as the premises and rules of scientific reasoning. Play is always a more or less abstract activity, during which it is possible to decide exactly how to behave - as in analysing propositions in logic - either by respecting the established rules or by breaking them (which involves cheating, that may result in disqualification - corresponding to a wrong step in logical analysis).

Play as an activity is self-sufficient, just as the language of a scientific discourse tends to be. This essential aspect of play is borne out by its exceptional, out-of-the-ordinary nature, compared with day-to-day living, whose rules were not chosen by man but imposed on him from outside.

Dienes' play materials demonstrate this in a particularly striking fashion. The blocks have no inherent significance. It is only in the act of play that they take on any meaning (for example, the formation of Venn's diagrams).

The analogy between play and science, based on their respective self-sufficiency, cannot be disputed. And does not this self-sufficiency represent the ideal condition for treating abstract concepts with complete certainty?

But modern mathematics is not the only branch of science which lends itself to play activities; all branches of the natural sciences, where experiment plays a major role, could be adapted to similar activities.

One may nevertheless wonder whether the element of play present in such operations does not preclude memorisation and the integration of knowledge into daily existence, and also to what extent such integration might be dispensed with in adult education. These questions, in spite of their importance, remain unanswered.

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CONCLUSION

The seminar at St. Wolfgang would appear to have raised more questions than it actually answered. This is explained by the novelty of the problems posed. Before solutions can be found, a certain number of relationships still have to be clarified, for example those connecting science and knowledge.

It does not appear possible to institute a valid form of science education for adults without communicating a certain body of knowledge - inevitably a painful process. The conditions of this communication pose a great many problems, which we have tried to touch upon with the help of the lectures delivered at Strobl. But this knowledge has not itself been defined. And that is perhaps fortunate, in the sense that a precise definition of knowledge for each science would be the first step towards dissociating knowledge from science. The former consists of what has been discovered, the latter of what is being discovered. The two notions are intimately related, but it is perhaps possible to be "scientific" without possessing great factual knowledge. It is this possibility, if it exists, which we believe should form the basis of a new teaching method which could be applied to adult education.

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